

Research Summary

Technologies for Detecting and Mapping Subsurface Voids Beneath Missouri Highways

Purpose

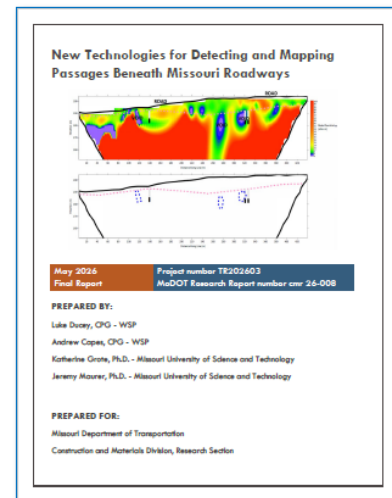
The Missouri Department of Transportation (MoDOT) sponsored this research to evaluate the application of geophysical and remote sensing technologies for identifying subsurface passages beneath highways, including caves, sinkholes, voids, and abandoned mine workings. These hazards are common in Missouri's karst terrain and historic mining districts and can lead to sudden collapse, emergency repairs, traffic disruptions, and increased risk to the traveling public.

Approach

WSP USA Inc. and Missouri University of Science and Technology (Missouri S&T) conducted the study by synthesizing published literature, DOT practices, and representative case histories to compare methods by depth of investigation, sensitivity to voids, deployment requirements, data quality, and key limitations. Findings were combined into a practical, phased framework to help MoDOT select defensible investigation strategies for suspected voids beneath roadways.

Methods were assessed across surface-based, borehole, and remote sensing workflows, including:

- Electrical Methods: Electrical Resistivity Tomography (ERT) and Transient Electromagnetic (TEM)
- Radar: Ground Penetrating Radar (GPR)
- Seismic: Refraction and Multichannel Analysis of Surface Waves (MASW)



- Potential Field Methods: Microgravity and Magnetometry
- Remote Sensing: LiDAR and InSAR
- Emerging: Muography
- Verification: Targeted drilling investigations with selected borehole geophysics

Key Findings

Void detection is highly site-specific; no single method is universally effective. Strong programs integrate multiple techniques in a logical, risk-based sequence and then verify anomalies with direct investigation.

Electrical Resistivity Tomography (ERT) emerged as the most reliable primary imaging tool for Missouri highway applications. It can delineate air-filled voids (high resistivity), water-filled cavities (low resistivity), collapse features, and weakened zones, and has been repeatedly validated through drilling in DOT and consultant case histories.

Ground Penetrating Radar (GPR) is useful for shallow, rapid corridor screening in non-conductive materials, but performance drops in clay-rich or electrically conductive soils common in parts of Missouri; it is best used as a supplemental tool.

Seismic methods (MASW and refraction) help define bedrock depth, stiffness, and fractured zones and can be paired with ERT to strengthen interpretation



and differentiate competent rock from collapse-prone areas.

Microgravity testing can detect large, deep density contrasts but requires specialized acquisition and expert interpretation. LiDAR and InSAR are effective regional screening and monitoring tools for identifying subtle surface deformations, such as sinkholes or historical slope scarps and prioritizing sites for detailed subsurface work, though voids cannot be directly imaged.

Borehole drilling and geophysics remain essential for confirming void geometry, depth, and materials after surface anomalies are identified, reducing uncertainty and supporting engineering decisions.

Case histories indicate the most effective efforts use early screening, targeted subsurface imaging, and focused verification-scaling to assess site-specific risk and prioritize locations with the highest potential for impacts to safety for the asset(s).

Recommended Framework for MoDOT

MoDOT should apply a phased, risk-based process that begins with a desktop study (e.g., GeoSTRAT, geologic mapping, LiDAR, historic mine records, and maintenance history) to flag and prioritize high-risk locations. Where karst features, sinkholes, or abandoned mine workings are suspected, ERT should serve as the primary subsurface imaging method, with GPR, seismic techniques, and/or microgravity applied selectively based on site conditions, objectives, and required resolution.

Targeted drilling can also serve a dual purpose as an early repair of some or all of the anomalies being confirmed, depending upon size and extent, at completion of the drilling exploration; by utilizing grouts or Controlled Low Strength Materials (CLSM), i.e. Flowable fills, during backfill of the boreholes.

Benefits

A consistent, statewide investigation approach improves early detection of subsurface hazards,

reduces emergency response and unplanned closures, and supports a shift from reactive repairs to proactive, risk-based management - strengthening the safety, reliability, and resilience of Missouri's highway systems.

"With approximately 7,500 recorded caves in the state, Missouri has become known as the Cave State." - MDNR

Project Information

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